MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2017/2018

ETM4106 – OPTOELECTRONICS AND OPTICAL COMMUNICATIONS

(TE)

3 MARCH 2018
2.30 p.m - 4.30 p.m
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 5 pages with 5 Questions only.

2. Attempt **ALL (5)** questions. All questions carry equal marks and the distribution of the marks for each question is given.

3. Please write all your answers in the Answer Booklet provided.

Question 1

(a) A typical single mode optical fiber has a core diameter of 6 μm and a refractive index of 1.45. The normalized refractive index difference is 0.25%. The cladding diameter is 120 μm. Find the numerical aperture and the acceptance angle of the optical fiber. [5 marks]

(b)(i) What is meant by mode for a guided optical fiber? [2 marks]

(ii) Explain the mode coupling in optical fiber. [2 marks]

(c) What is the cutoff normalized frequency for the LP_{01} mode in step index fiber under single-mode operation? [2 marks]

(d) Find the number of allowed modes in a multimode step index optical fiber that has a core refractive index of 1.465 and diameter of 100 μm, and a cladding refractive index of 1.445 if the LED wavelength is 820 nm. [5 marks]

(e)(i) Give two examples of oxide material suitable for fiber preparation using liquid-phase techniques. [2 marks]

(ii) Explain an advantage of using Plasma-activated chemical vapour deposition technique. [2 marks]

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Question 2

(a)(i) Define the decibel (dB) and write the formula to determine the signal loss in optical fiber. [1 + 1 marks]

(ii) Give the two major sources of signal loss due to extrinsic absorption in optical fiber. [2 marks]

(b)(i) Explain the stimulated Raman scattering in optical fiber. [4 marks]

(ii) A single-mode optical fiber has an attenuation of 0.5 dB/km when operating at a wavelength of 1.33 μm. The fiber core radius is 2.5 μm and the laser source bandwidth is 600 MHz. Find the threshold optical power for stimulated Raman scattering in this fiber. [4 marks]

(c) Explain the following terms for optical fiber dispersion

(i) Intermodal dispersion [2 marks]

(ii) Intramodal dispersion [2 marks]

(d) An optical fiber coupler is a device that distributes light from a main fiber into one or more branch fibers. What are the two major categories of optical fiber couplers? [4 marks]

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Question 3

(a)(i) Explain the population inversion in a p-n junction semiconductor. [2 marks]

(ii) Give an example of double-heterojunction material system which is best developed and is used for fabricating both laser diodes and LEDs for the short wavelength region (i.e. 0.8 – 0.9 μm). [2 marks]

(iii) The double-heterojunction laser structure provides optical confinement in the vertical direction through refractive index step at the heterojunction interfaces. State the problems in this laser structure and how to overcome the stated problems. [2 + 2 marks]

(b)(i) List the two main sources of noise in photodiodes without internal gain. [2 marks]

(ii) Give the expression of total shot noise for part (i) including the background radiation induced photocurrent. [2 marks]

(c)(i) Determine the quantum efficiency of the photodiode operating at 820 nm when 4.0×10^{11} photons are incident on this photodiode. The average of 1.5×10^{11} electrons are collected at the terminals of the device. [2 marks]

(ii) A p-i-n photodiode ceases to operate when photons with energy greater than 0.888 eV are incident upon it. Suggest a suitable material to fabricate this photodiode. [2 marks]

(d) An avalanche photodiode with a multiplication factor of 28 operates at a wavelength of 1.52 μm. Calculate the quantum efficiency and the output photocurrent from the device if its responsivity at this wavelength is 0.6 A/W and the received optical power is 0.5 μW. [2 + 2 marks]

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Question 4

(a)(i) Is optical amplifier operates in the electrical domain? Justify your answer. [1 + 1 marks]

(ii) List the difference of facet reflectivities in between travelling wave amplifier and Fabry-Perot amplifier. [2 marks]

(iii) Give an example of rare earth doped fiber amplifier. [2 marks]

(b) Show the phase change, $\delta\phi$ for light operating at wavelength, λ in a simple strip waveguide phase modulator is given by

$$\delta\phi = \frac{\pi}{\lambda} n_1^3 r \frac{VL}{d}$$

, where n_1 is the refractive index, r is the electro-optic coefficient, V is the applied voltage, L is the length of the electrode and d is the distance between electrodes. [4 marks]

(c) An analog optical fiber system uses direct modulation of the optical source intensity with the baseband signal. Does it require the electrical modulation or demodulation in this technique? Explain your answer. [1 + 1 marks]

(d) The technology of combining a number of wavelengths onto the same fiber is known as wavelength-division multiplexing (WDM). State the four key system features of WDM. [4 × 2 marks]

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Question 5

(a) Communication using an optical carrier wave guided along a glass fiber has a number of advantages over electrical communication. Give your comment on the following advantages

(i) Immunity to interference and crosstalk [2 marks]
(ii) Signal security [2 marks]
(iii) Low transmission loss [2 marks]

(b)(i) Write an expression of optical power budget for a digital optical communication system including the safety margin and a dispersion-equalization penalty. [3 marks]

(ii) What is safety margin or operating margin in optical power budget equation? [2 marks]

(c) An optical fiber system is designed to operate over a 10 km length without repeaters. The rise times of the chosen components are

Source (LED)	8 ns
Fiber: intermodal	5 ns/km
intramodal	1 ns/km
Detector (p-i-n photodiode)	6 ns

Determine the maximum bit rate that may be achieved on the fiber link when using an NRZ format. [5 marks]

(d) Many problems associated with the design of optical fiber communication system occur as a result of the unique properties of the glass fiber as a transmission medium. It is essential that certain basic system requirements are specified. List down four specifications for this optical system. [4 marks]

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